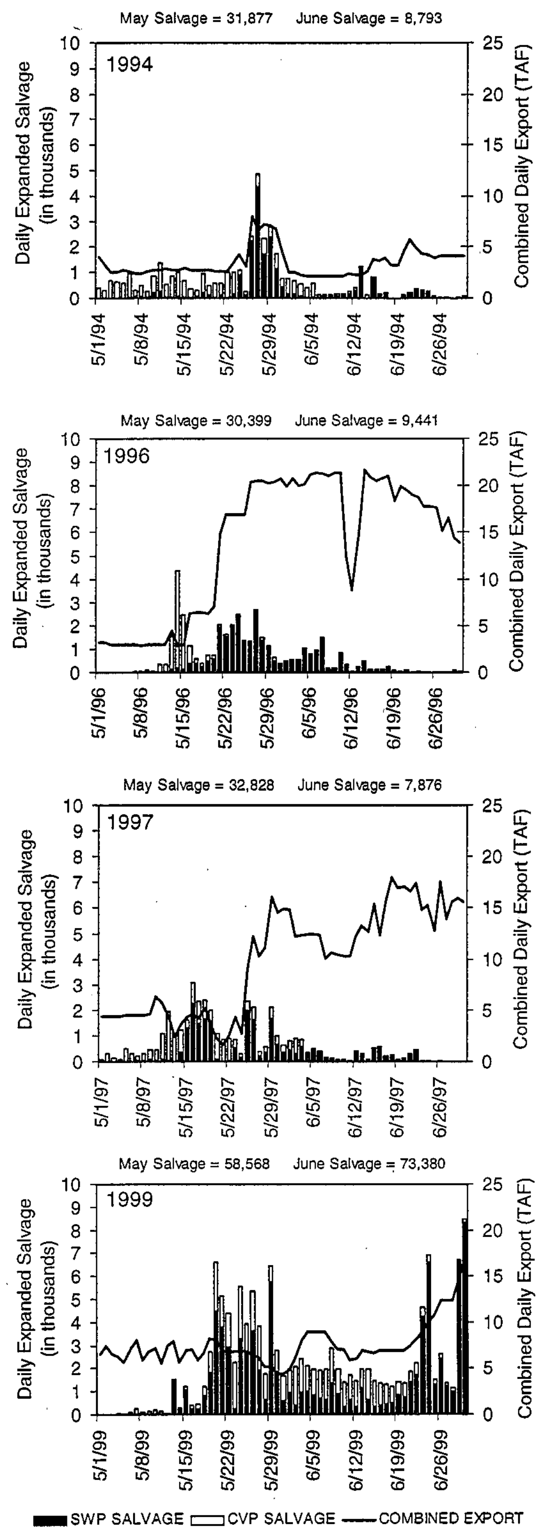

Figure 2 State and federal delta smelt salvage from May through June during the last four years that take exceeded a red light level. The daily red light level for any given month in 1994 was 400. For all subsequent years, the monthly red light level for May was 9,769 and for June was 10,709.

In 1999, the combined CVP and SWP delta smelt salvage increased dramatically during May. Only delta smelt longer than 20 mm are considered to be "take" in the salvage operations. The yellow light level was exceeded by 18 May, and the red light level (9,769 delta smelt) was exceeded by 16 May. Combined salvage remained high throughout the month, and by the end of May total monthly salvage (58,568 delta smelt) exceeded the red light level six fold.

Take remained high in June as well. The June red light level (10,709 delta smelt) was exceeded by 6 June. By the end of June, combined monthly salvage (73,380 delta smelt) exceeded the red light level by nearly seven fold. During the past six years the projects have exceeded the red light level in May four times (see Figure 2), but this is the first year the projects have exceeded the red light level two months in a row. This year's June salvage is particularly anomalous since delta smelt have usually moved downstream by June. June salvage this year exceeded the previous high of 45,913 delta smelt salvaged in June 1981.

Maintaining low export levels has been the primary action for minimizing delta smelt take this year. Substantial export reductions have occurred. By the end of June, exports were more than 400,000 acre-feet lower than what would have occurred in the absence of delta smelt concerns. Export/Inflow (E/I) ratios have ranged from about 9% to 22% during May and most of June. The E/I ratio did not approach the 35% limit specified by the delta smelt biological opinion until June 28. Two south Delta temporary barriers have been operational (Middle River and Old River near Tracy). The Grant Line Canal barrier is in place, but it is being held open to reduce reverse flow in Old River.

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Wind and Rough Weather Decrease Captured Delta Smelt Survival

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Delta smelt, *Hypomesus transpacificus*, is a small, threatened osmerid, native to the Sacramento-San Joaquin Delta. Laboratory studies on delta smelt, such as the Fish Treadmill Project (Swanson and others 1998), are usually limited by fish availability and transport survival. Because of their highly delicate nature, delta smelt survival after collection, handling and transport has been unpredictable even with consistent handling methods. This study aimed at determining the environmental factors that affect the 24 and 48 h survival of delta smelt in the laboratory, after collection, handling, and transport from the Delta.

Methods

Delta smelt were collected from various sites in the Sacramento-San Joaquin Delta from July to November 1997, and from August to December 1998 (specific conductance ranging from 200 to 2,000 µmho/cm) using a 40 m long, 4 m deep, 2 mm mesh purse seine—similar to method in Swanson and others (1996). At the end of each set, the pursed net was pulled to one side of the boat and fish were removed from the net using a polyethylene bag dip net and placed in a bucket with 4 to 6 ppt salinity and 0.5 ml/L NovAqua. Addition of salt and NovAqua, a synthetic polymer, to transport medium was intended to reduce stress-induced osmotic imbalance. Fish were counted and placed into vertical polyethylene bags containing 10 L of estuary water with 4 to 6 ppt salinity and 0.5 ml/L NovAqua. Four bags were set inside a 60 L plastic chest cooler on top of 10 cm polyurethane foam sheet. After the bag was stocked with fish (maximum: 50 per bag), the air in the bag (about one-third of its volume) was squeezed out and replaced with medical-grade oxygen and the bag sealed. A thin layer of crushed ice was placed outside the bags to maintain the water temperature ±1 °C. However, during late fall and early winter, when the Delta water temperatures were below 10 °C, we did not put crushed ice on the transport bags, and temperature in the bag did not increase >0.5 °C during transit. Variables such as date, time of collection, temperature, specific conductance, weather, wind, surface water, and total smelt collected were noted. Survival data were available for 16 collection days in 1997 and 26 collection days in 1998. During the second year of the study, an outer black polyethylene bag was used over the translucent transport bag to reduce light, and another 10 cm polyurethane foam sheet was placed inside the plastic chest cooler to reduce agitation. Additionally, length of transport time (water transport, land transport, and total transport) was also noted on 18 collection days of the second year.

Upon arrival at the Aquatic Center at the Institute of Ecology (University of California, Davis), temperatures of the transport bags and the 250 L holding tank were remeasured. Holding tanks were supplied with non-chlorinated, air-equilibrated, temperature-controlled well water with brine drip system to maintain tank water at 4 to 6 ppt. When holding tank temperature was higher than the transport bag, 4 to 5 gallon size bags with crushed ice were floated on the holding tank until the temperature in the bags and tank were equilibrated before releasing the fish into the tank. Holding tank water was maintained at 4 to 6 ppt salinity by a brine drip system and 10 ml of NovAqua was added before the fish were released into the tank. The tank was enclosed with black plastic to minimize illumination and disturbance. Dead fish in the tank were removed and measured each day. The rest of the fish were fed with *Artemia* nauplii (1,000 nauplii per liter) twice a day and a commercial diet (Biokyowa, Inc.) throughout the day.

Percent survival was calculated 24 h (day 1) and 48 h (day 2) after collection. Besides a least squares regression analysis, a principal component analysis (PCA) was conducted because of significant correlations ($P < 0.05$) among some of the variables. We used orthogonally rotated data on factors that explained 95% of the variation of the original set of independent variables. Data for 1997 and 1998 were pooled for statistical analyses because the significant regressors ($P < 0.05$) showed similar trends for both years.

RESULTS AND DISCUSSION

Regression analyses showed that survival rates were significantly correlated ($P < 0.05$) with date of collection, Delta water temperature, wind condition, and surface water condition. Other variables such as weather, specific conductance, transport time, start of collection time, day and night phase, and total catch were not significantly correlated ($P < 0.05$) with survival. PCA results indicated that one group of correlated variables consists of date of collection (time of year) and field temperature. Because fish collection started during the summer, water temperature gradually decreased as the date progressed (Figure 1). Another group consists of weather, wind, and surface water condition. As one variable got worse, so did the others. Water surface condition was significantly affected ($P < 0.05$) by wind condition (Figure 2). The first group (collection date and temperature) explained 28% of the variation in survival rate, while the second group (weather, wind and surface water condition) explained 51% of the variation.

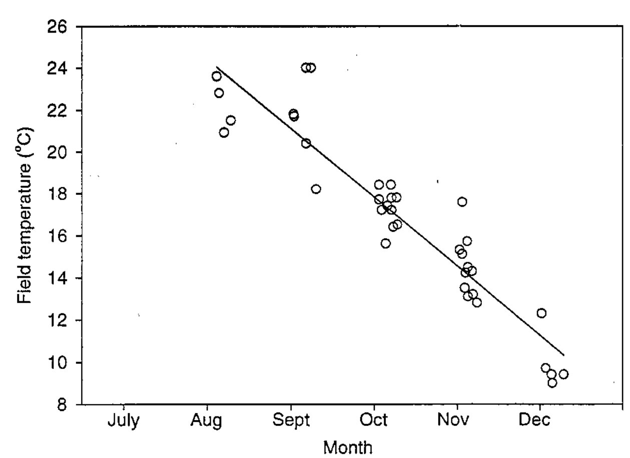

Figure 1 Delta water temperatures during the delta smelt period in 1997 and 1998

Day 1 and Day 2 survival rates increased as collection date progressed during the year (Figure 3A) and as temperature decreased (Figure 3B). Decreases in temperature decrease metabolic rate, locomotor activity, oxygen consumption, and stress-induced osmotic imbalance in fish (Reynolds and Casterlin 1980; Moyle and Cech 1996). Another reason for increased survival as date progressed may be the increase in fish size. Delta smelt rarely survive for >1 year, and smaller fish may be more sensitive to handling and transport stress.

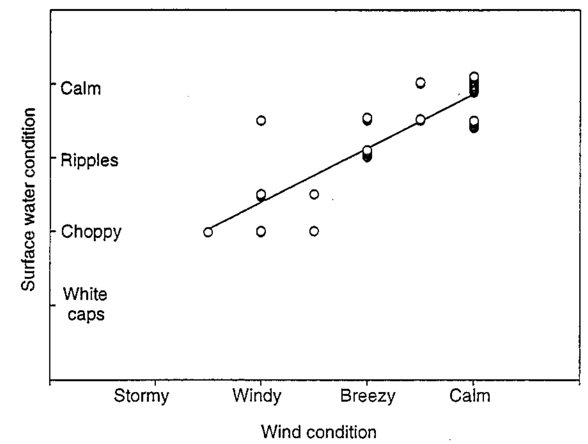

Figure 2 Relationship between surface conditions and wind conditions in the Sacramento-San Joaquin Delta. Data slightly adjusted to show overlapping symbols.

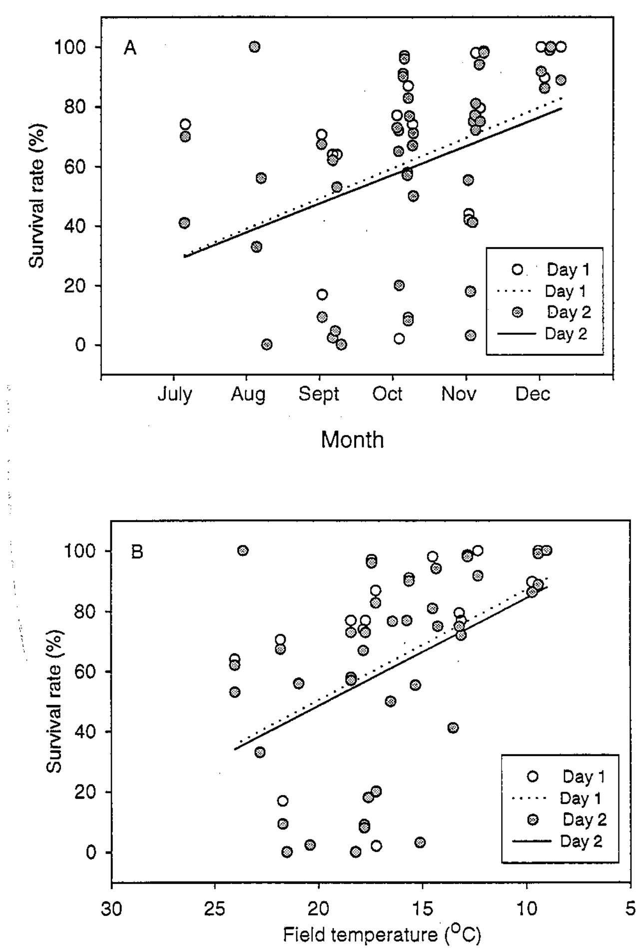

Figure 3 Delta smelt survival rates in relation to (A) time of year collected and (B) Delta water temperatures

Survival rates increased with calmer wind and surface water conditions (Figure 4). During conditions when high wind and rough surface water lurched the boat, the pursed net was often partially exposed to air. Thus, some fish were exposed to air or impinged against the net while being collected. This made the fish collection more difficult and time spent on collecting longer. After collection in rough water, the boat ride back to the dock pitched the transport containers back and forth, and sloshed the water inside the transport bags. This could result in fish striking the side of the bag and exposing the fish to turbulence. This trauma seemed to be very stressful to the delta smelt. During rough days, many fish had lost equilibrium upon arrival at the laboratory.

For increased delta smelt survival, we recommend that they be collected when wind and surface water are relatively calm and when water temperatures are <15 °C.

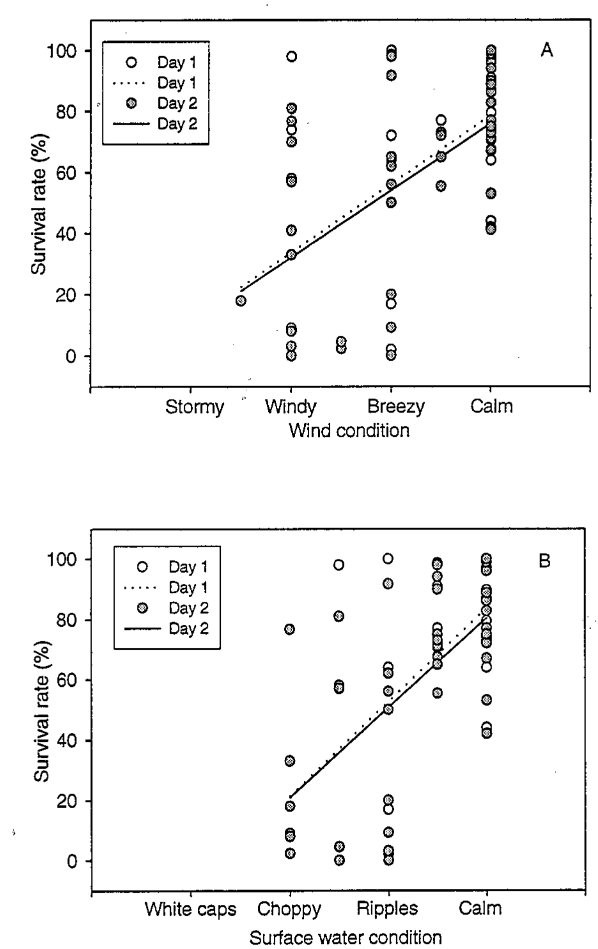

Figure 4 Delta smelt survival rates in relation to (A) wind conditions and (B) surface water conditions

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MEASURED FLOW AND TRACER-DYE DATA FOR SPRING 1997 AND 1998 FOR THE SOUTH SACRAMENTO-SAN JOAQUIN DELTA, CALIFORNIA

Richard N. Oltmann, USGS

INTRODUCTION

During the spring of years when the flow of the San Joaquin River is less than 7,000 cubic feet per second (ft^3/s) a temporary rock barrier is installed by the California Department of Water Resources (DWR) at the head of Old River (HOR) in the south Sacramento-San Joaquin Delta to prevent out migrating salmon in the San Joaquin River from entering Old River and being drawn to the State and federal pumping facilities (Figure 1). The export rate of the pumping facilities also is reduced during these migration periods to minimize the draw of fish to the export facilities through the other channels connected to the San Joaquin River north of the HOR such as Turner Cut, Columbia Cut, and Middle River.